Small-scale nuclear reactors for remote military operations: opportunities and challenges

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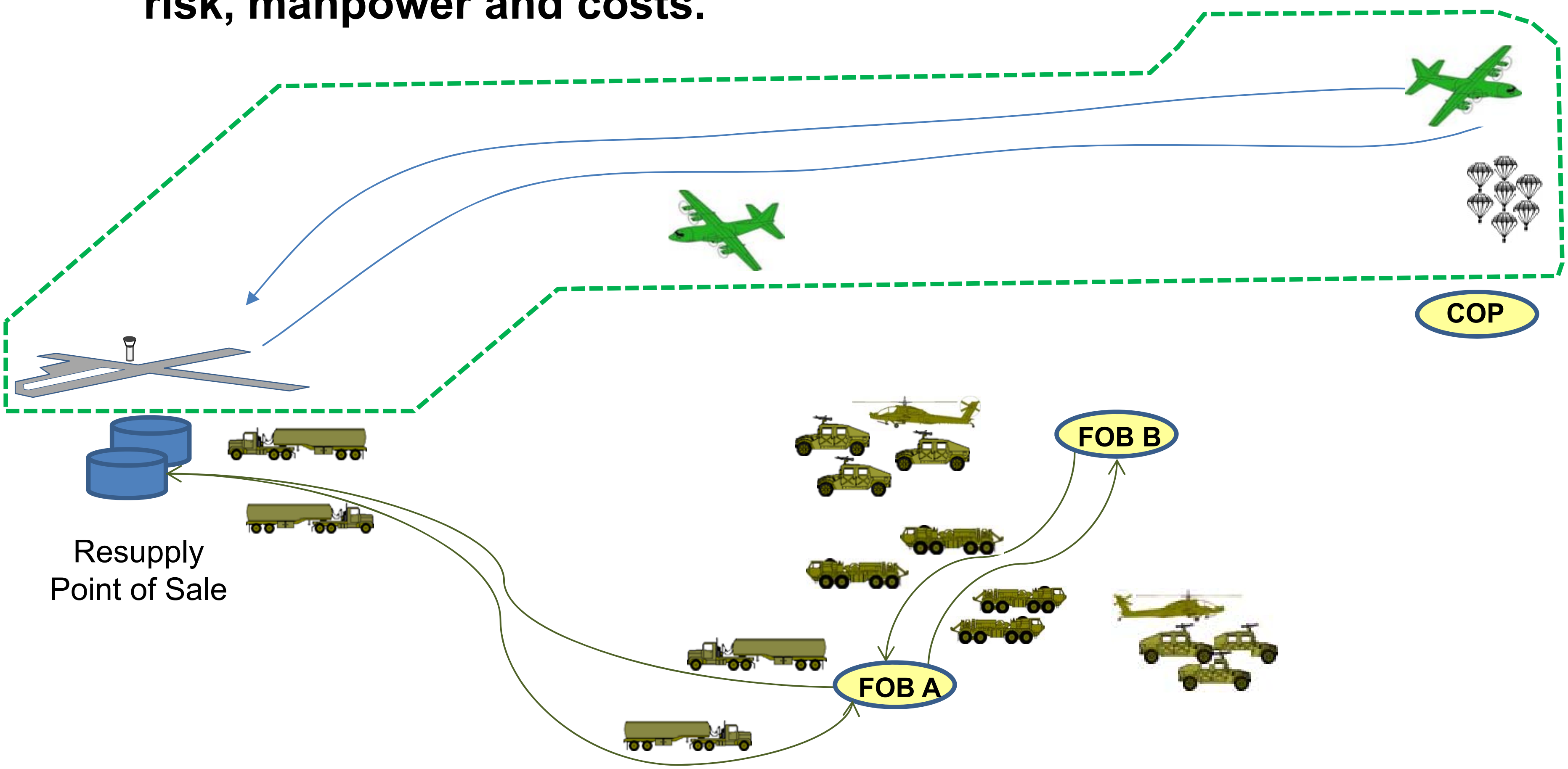
Presentation Outline

- ❑ **The appeal of nuclear power for military applications**
- ❑ **DoD’s previous research initiatives and expressions of interest regarding terrestrial small modular (nuclear) reactor R&D**
  - Army Nuclear Reactor Program (1950s-1970s)
  - Recent DoD science board recommendations related to nuclear energy (2009 & 2012)
  - DARPA RFI/Study on deployable SMRs (2010)
  - Center for Naval Analyses Study on SMRs for installations (2011)
- ❑ **Ongoing Defense Science Board Study on Energy Systems for Forward & Remote Operating Bases (2014-Present)**

Challenge: Ground Force Delivery Logistics

- Remote and Forward Operating Bases (FOBs) lack infrastructure, and require significant quantities of energy and water.
- Delivery of supplies entails significant mission risk, personnel risk, manpower and costs.



Appeal of Nuclear: Energy Density

Table 6 Energy Densities of Various Fuels

Energy Sources	Energy Density (kilojoules per cubic centimeter)	
Solar, Wind	NA (diffuse)	Clean and abundant, with diffuse, intermittent availability Valuable supplemental sources
Electrochemical	3–5	Primary source for personal power Development driven by commercial markets
Fossil fuels	20–35	Gasoline = 35 Primary source for vehicle propulsion and power, base power
Radioisotopes	> 100,000	Significant untapped potential
Compact fission reactor	> 10,000,000	Significant untapped potential

DSB. (2013). *2012 Summer Study on Technology and Innovation Enablers for Superiority in 2030*. Defense Science Board, Washington, D.C.

Former Army Nuclear Power Program

SM-1

US Army ML-1 Reactor, 1962

MH-1A (aka "Sturgis")

Reactor	First Criticality	Description	Application
SM-1	April 1957	2 MWe, located in Fort Belvoir	Multi-service training reactor; first reactor on an electrical grid
SL-1	January 1961	300 kWe, located at Idaho National Laboratory, test boiling water reactor for remote DEW radar station power	Prototype for remote DEW radar station power plant.
PM-2A	October 1960	2 MWe, located at Camp Century, Greenland,	Prefabricated component reactor moved to site, assembled, operated, and removed
ML-1	March 1961	300 to 500 kW, portable gas-cooled reactor	Truck, rail, or barge transportable
PM-1	February 1962	1.25 MWe, Sundance Air Force Station, pressurized water reactor	Provided power for radar station
PM-3A	March 1962	1.75 MWe, McMurdo Station, Antarctica	Portable reactor for heat, water, and power; disassembled and returned to the United States
SM-1A	March 1962	2 MWe, Fort Greely, Alaska	Development reactor
MH-1A	January 1967	10 MWe, Panama Canal, barge mounted	Power and water supply

Table from: Griffith, G. (2015). *US Forward Operating Base Applications of Nuclear Power*. Idaho National Laboratory (INL), Idaho Falls, ID.

Recent DoD Science Board Recommendations

- **USAF SAB Report 2009, Recommendation 4: Make nuclear energy part of AF energy planning**
  - Evaluate a nuclear power generation option for selected bases, perform technical evaluation, engage Services/ DOE/ Industry for a concept demonstration.
- **DSB 2012 Summer Study, Recommendation 8:**
  - USD(AT&L) direct DARPA to fund applied research to develop and demonstrate safe, affordable, transportable, lightweight radioisotope batteries that provide ~5 W of power continuously for 3 to 5 years.
  - USD(AT&L) to convene a working group to address policy, regulatory, and related issues.

Woodard, M., and Sailor, J. (2009). *Alternative Sources of Energy for U.S. Air Force Bases*. United States Air Force Scientific Advisory Board.

DSB. (2013). *2012 Summer Study on Technology and Innovation Enablers for Superiority in 2030*. Defense Science Board, Washington, D.C.

DARPA 2010 Request for Information (RFI)

- RFI on Deployable Reactor Technologies for Generating Power and Logistic Fuels (March 2010)
  - Seeking technologies for generation of electrical power and military logistic fuels (using available indigenous feedstocks) in forward land based and maritime military operations.
    - inherently safe
    - do not produce waste products which would contribute to proliferation problems
    - total output of 5 to 10 MWe, and 15,000 gal/day fuel

https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=d0792af88a6a4484b3aa9d0dfeaaf553&_cview=0

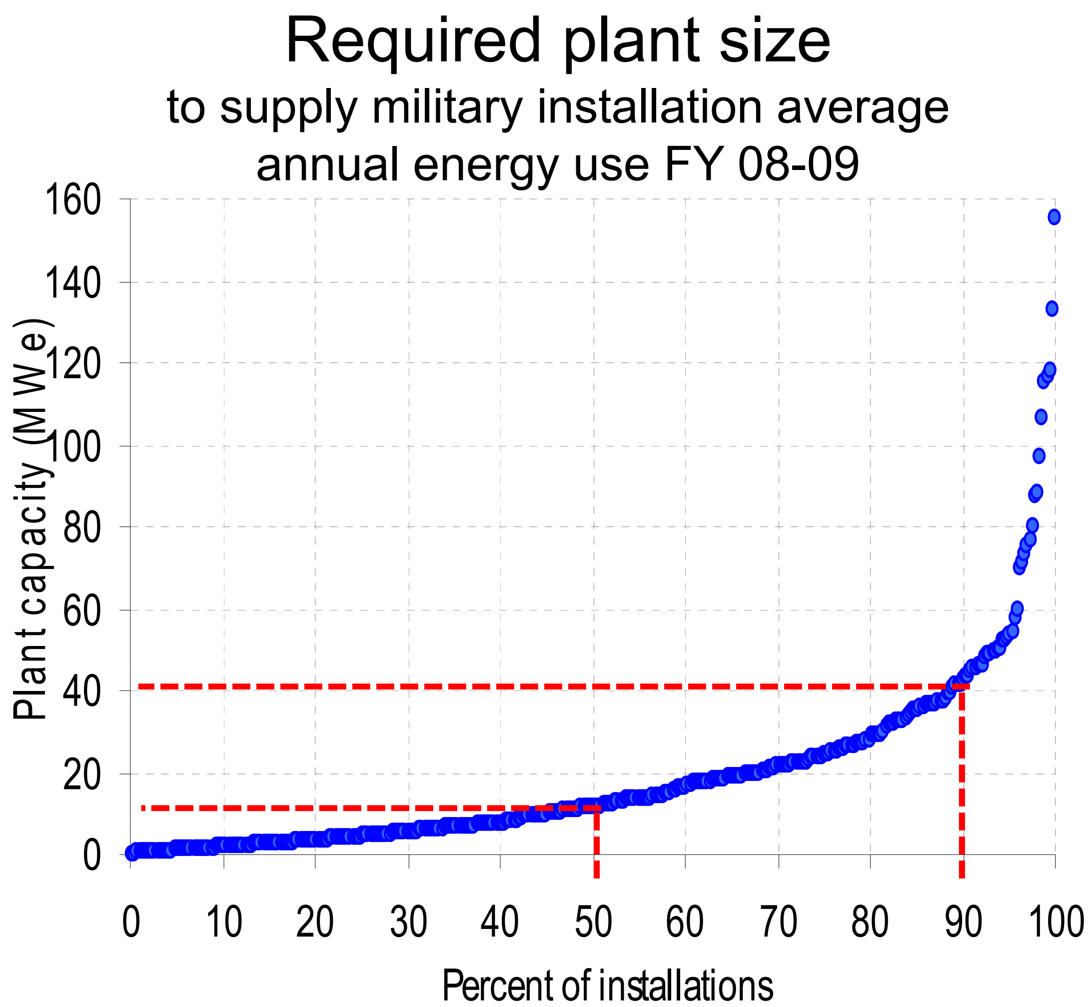
CNA Study: Nuclear Power for Installations

- **FY2010 National Defense Authorization Act (NDAA) requested a report on SMRs for DoD installations.**
- **DoD commissioned Center for Naval Analysis (CNA) to perform the study**
  - Report was published in March 2011
- **CNA study identified challenges to deploy small modular reactors (SMRs) at a base**
  - Identified First-of-a-Kind (FOAK) expenses for SMR deployment
  - Recognized technology issues associated with plant size
  - Addressed technical and licensing issues for development

King, M., Huntzinger, L., and Nguyen, T. (2011). "Feasibility of Nuclear Power on US Military Installations (2nd Revision)." Washington, DC.

CNA Study – Sizing SMRs for DoD Installations

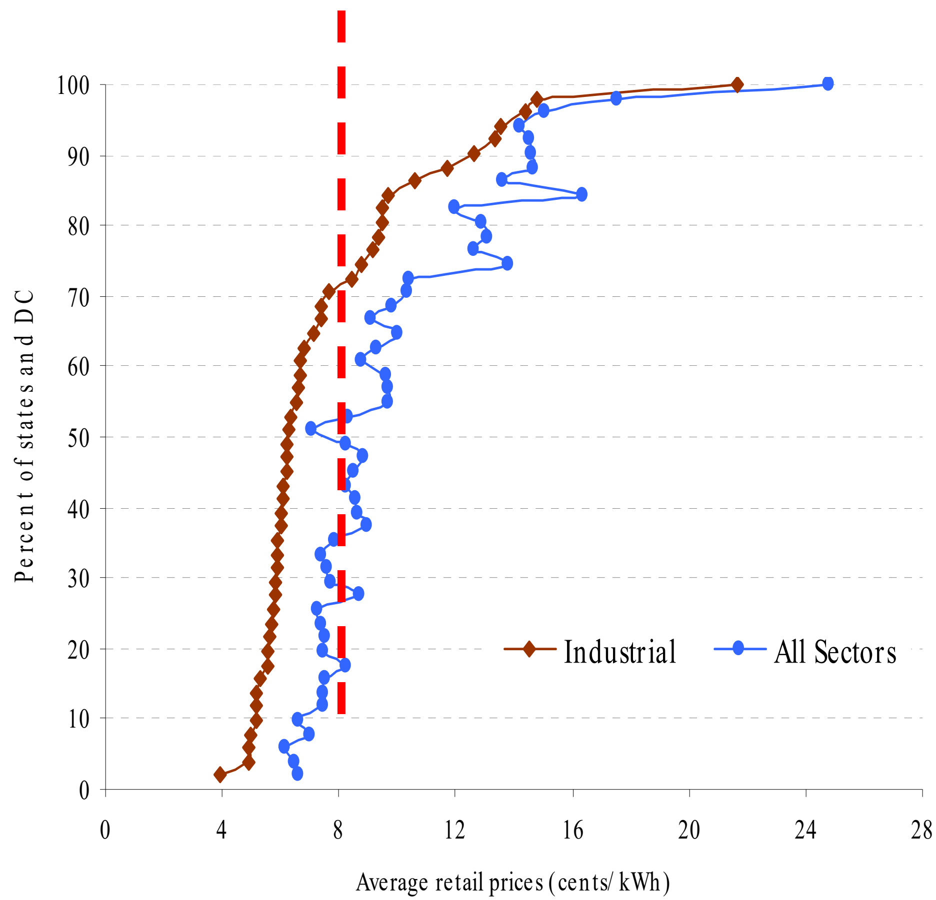
- **DOE is targeting ~185 MWe and ~45 MWe designs for SMRs**
  - Improved safety
  - Factory manufacture
  - Use as single, or group
- **90% of military installations require <40 MWe of power; ~50% require <10MWe**



King, M., Huntzinger, L., and Nguyen, T. (2011). "Feasibility of Nuclear Power on US Military Installations (2nd Revision)." Washington, DC.

CNA Study – SMR Economic Viability

- **Substantial FOAK expenses ~ $800 million (can be paid by some combination of USG and private sector funding)**
- **If FOAK expenses are excluded, estimated levelized cost of electricity ~$0.08 per kWh**
- **Potential benefits to DoD:**
  - Increase energy assurance
  - Reduce carbon emissions
  - Viable price, if DoD does not pay FOAK expenses
- **Issues requiring time & money:**
  - safety, certification, licensing, construction and operations

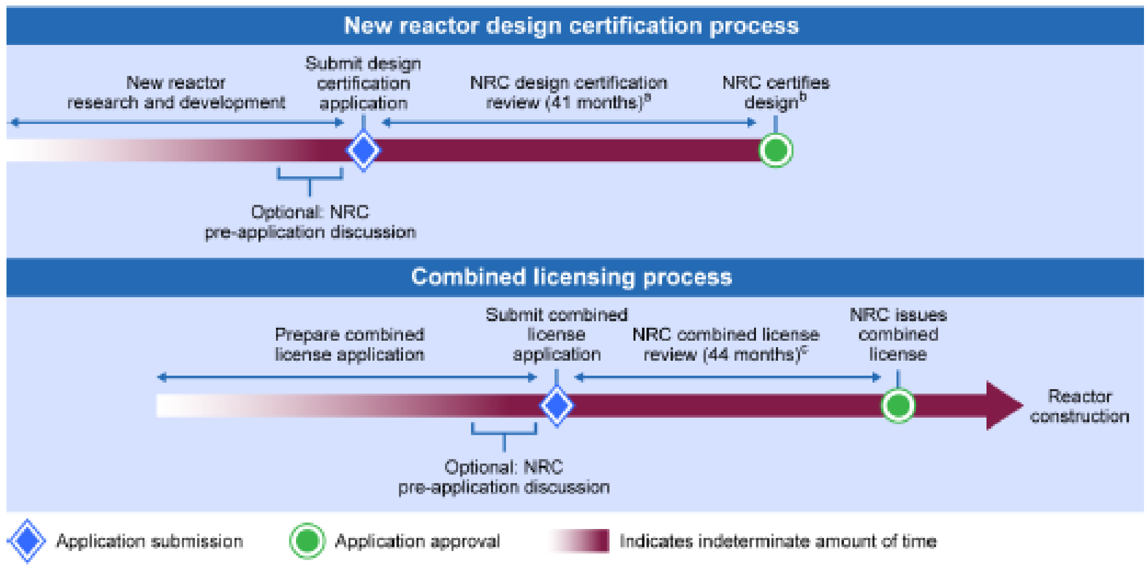


King, M., Huntzinger, L., and Nguyen, T. (2011). "Feasibility of Nuclear Power on US Military Installations (2nd Revision)." Washington, DC.

GAO: First SMR in United States unlikely to be operational before 2023

- 1st SMR application (NuScale) to NRC expected in 2016; operation expected 2023.
- No advanced (non-LW) reactors expected to submit NRC application before 2020.

Figure 2 Overview of Nuclear Regulatory Commission's (NRC) Part 52 licensing process with notional time frames



Source: GAO, based on Nuclear Regulatory Commission documentation. | GAO-15-652

US GAO. (2015). *Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts*. Technology Assessment, US Government Accountability Office, Washington, D.C.

- Some experts believe that new reactor designs would require 20-25 years for development and approval through NRC (or through DoD, if the DoD's authority to manage a nuclear energy program is exercised).

Griffith, G. (2015). *US Forward Operating Base Applications of Nuclear Power*. Idaho National Laboratory (INL), Idaho Falls, ID.

FY 14 NDAA SASC Requirement for SMR study

The **committee continues to be concerned about the survivability, sustainability, and significant logistical costs of fuel and water** associated with the support of deployed personnel at remote forward operating bases. The availability of deployable, cost-effective, regulated, and secure **small modular reactors** with a modest output electrical power (**less than 10 megawatts**) **could improve combat capability** and improve deployed conditions for the Department of Defense (DOD).

The committee understands the pursuit of **such an endeavor invites ample concerns**, not limited to: technical feasibility, policy oversight and regulation, robust safety and secure design features, logistics and resources, proliferation concerns, life cycle costs, deployment policies and transportability, personnel costs, and lessons learned from recent combat operations.

Therefore, the committee directs the DOD to submit a report to the congressional defense committees on the **challenges, operational requirements, constraints, cost, and life cycle analysis for a small modular reactor of less than 10 megawatts** no later than January 1, 2015.

Timeline: From NDAA request to DSB Study

- Language from FY14 National Defense Authorization Act (NDAA), released in **June 2013,** was incorporated into Terms of Reference for a Defense Science Board (DSB) study to address energy challenges and potentially applicable technologies for remote and forward operating bases.
- Terms of Reference were signed by the Under Secretary of Defense (AT&L) in **February 2014**.
- Interim Letter to Congress in December 2014 stated an anticipated completion date of **November 2015**.

DSB Task Force Leadership

❑ Sponsor

- The Honorable Frank Kendall, USD (AT&L)

❑ Task Force Co-Chairs

- General Paul Kern, US Army (retired)
- Dr. Michael Anastasio, Director Emeritus, Los Alamos National Lab

❑ Task Force Members

- ADM (Ret.) Frank “Skip” Bowman
- MGen (Ret.) Jan Edmunds
- Dr. Jerry Galloway
- Honorable William Schneider, Jr.
- Dr. William Madia

❑ Executive Secretary

- Dr. Bret Strogen, OUSD (AT&L) contractor

❑ DSB Secretariat Representative

- LTCOL Michael Harvey, US Air Force

DSB Study Terms of Reference (ToR)

- **Objectively evaluate different mechanisms to provide energy to forward, remote operating bases.**
  - Identify relevant factors (e.g. survivability, supportability, suitability, force protection requirements, etc.) of energy sources.
- **Examine feasibility of deployable, cost-effective, regulated, secure small modular reactors (SMRs) with an output <10 MW, by addressing:**
  - technical feasibility,
  - policy oversight and regulation,
  - robust safety and secure design features,
  - logistics and resources,
  - proliferation concerns,
  - life cycle costs,
  - deployment policies and transportability,
  - personnel costs, and
  - lessons learned from recent combat operations.

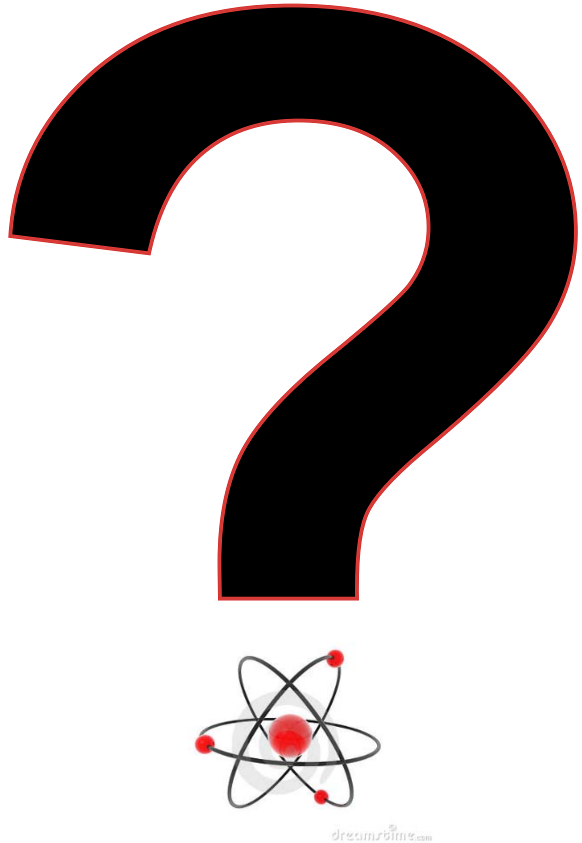
Discussion: Potential *KPPs for a FOB SMR*

- **Size & Transportability**
  - 25-40 tonnes
  - Truck or C-17 compatible
- **Outputs**
  - 2-10 MWe
  - Heat, water, fuel, or other metrics?
- **Ultimate heat sink**
  - Air (vs. water)
- **Time to shutdown, cool down, disconnect, and remove**
  - 6 hours to 7 days

- **Time to install**
  - 12-72 hours
- **Health & Safety**
  - No net increase in risk to public, military personnel, environment
  - No net increase in consequences of adversary attack

- **Proliferation risk**
  - None

Photos Courtesy of Los Alamos National Laboratory



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